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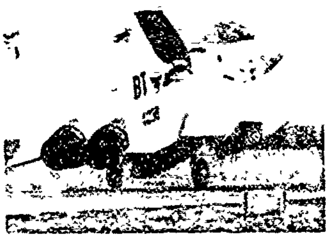
INVESTIGATION OF AIRFIELD PAVEMENT FAILURE AT CAIRO EAST AIR BASE

by

Randy C. Ahlrich

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199



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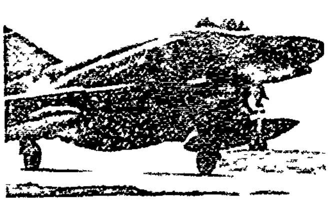

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13. ABSTRACT *(Maximum 200 words)*

The US Army Engineer Waterways Experiment Station (WES) was requested by the Middle East/Africa Projects Office in April 1989 to provide technical assistance in analyzing an unstable asphalt concrete airfield pavement. An asphalt concrete overlay had been constructed on an aircraft parking apron and taxiway. The asphalt concrete overlay had exhibited significant deformation and depressions under parked aircraft traffic. The performance of the unstable asphalt concrete pavement was unacceptable.

WES was requested to perform laboratory tests on asphalt concrete specimens to determine asphalt cement, aggregate, and asphalt concrete mixture properties. This analysis was to evaluate the in-place asphalt concrete material for compliance with specifications, determine possible causes for pavement failure, suggest procedures to avoid these problems in the future, and recommend options for the repair of this airfield pavement.

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The laboratory evaluation of the asphalt concrete material indicated that the poor performance was due to an improperly designed and produced asphalt concrete mixture. Several factors contributed to the unstable mixture: (1) the aggregate gradations were consistently out of specification and were gap graded, (2) the amount of natural sand in both the surface course and intermediate course was extremely high, and (3) the mix designs for the surface course and intermediate course mixtures did not meet the minimum requirements of the specification.

14. (Concluded).

Natural sand
Recompaction analysis
Rutting

PREFACE

This pavement investigation was conducted by the Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, for the US Army Corps of Engineers, Transatlantic Division, Middle East/Africa Project Office (MEAPO), Winchester, VA, to provide technical assistance in analyzing an unstable asphalt concrete airfield pavement at Cairo East Air Base, Egypt. This study was authorized by MEAPO in MIPR E87900125. This work was conducted from April 1989 to June 1990. The Technical Monitors were Dr. Roger Brown and Mr. Jamal Fakhouri of MEAPO.

The study was conducted under general supervision of Dr. William F. Marcuson III, Chief, GL; Mr. Harry H. Ulery, Jr., Chief, Pavement Systems Division (PSD); and Dr. Raymond S. Rollings, former Chief, Materials Research and Construction Technology Branch (MRCTB), PSD. This report was written under direct supervision of Mr. Timothy W. Vollor, Acting Chief, MRCTB, PSD. PSD personnel engaged in the testing, evaluating, and analysis of this project were Messrs. Jerry Duncan, Herbert McKnight, Tim McCaffrey, David Reed, and Joey Simmons. The project Principal Investigator was Mr. Randy C. Ahlrich who also wrote the report.

COL Larry B. Fulton, EN, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	2.54	centimetres
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

Investigation of Airfield Pavement Failure at Cairo East Air Base

PART I: INTRODUCTION

1. The US Army Engineer Waterways Experiment Station (WES) was requested by the US Army Corps of Engineers, Transatlantic Division, Middle East/Africa Projects Office (MEAPO) in April 1989 to provide technical assistance in analyzing an airfield pavement failure at Cairo East Air Base in Cairo, Egypt. An asphalt concrete overlay had been constructed on an airfield parking apron and taxiway. The asphalt concrete overlay had exhibited significant deformation and depressions under normal C-130 and C-141 aircraft traffic. The performance of the unstable asphalt concrete was unacceptable. Figures 1 through 4 show typical pavement distresses in the new asphalt concrete overlay.

2. The Materials Research and Construction Technology Branch of the Geotechnical Laboratory was requested to perform laboratory tests on asphalt concrete specimens to determine asphalt cement, aggregate, and asphalt concrete mixture properties. This analysis was to evaluate the in-place asphalt concrete materials for compliance with specifications, determine possible causes for the pavement failure, suggest procedures to avoid these problems in the future, and recommend options for the repair of this airfield pavement.

3. MEAPO also requested technical assistance during the repair and construction of the airfield pavement in February 1990. A visit to the construction site was required to monitor the production and construction of the pavement. Additional WES laboratory testing was conducted to evaluate new materials and determine why the WES laboratory data were not agreeing with the field laboratory data.

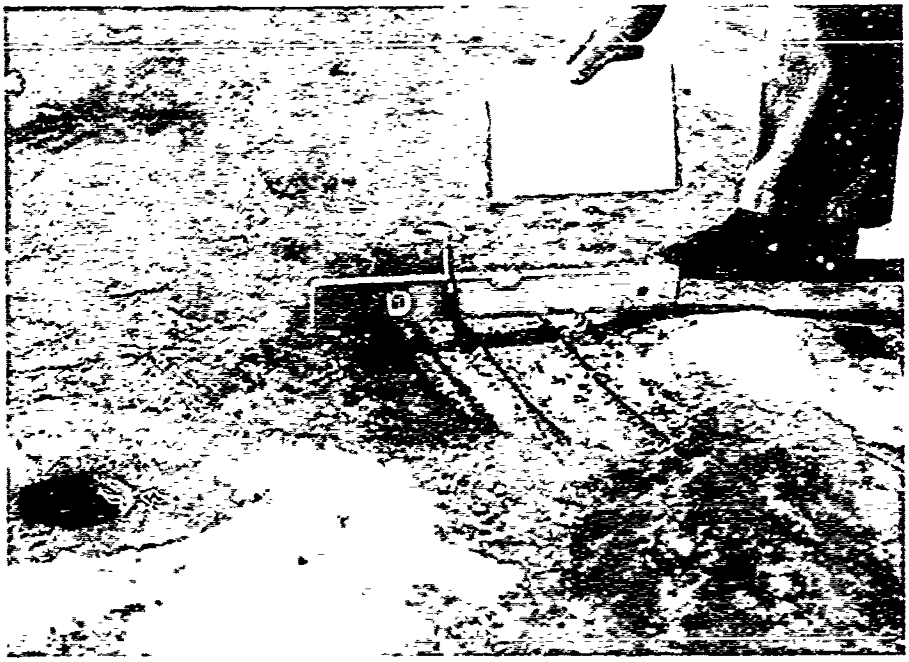

Figure 1. Severe pavement deformation caused by parked C-141

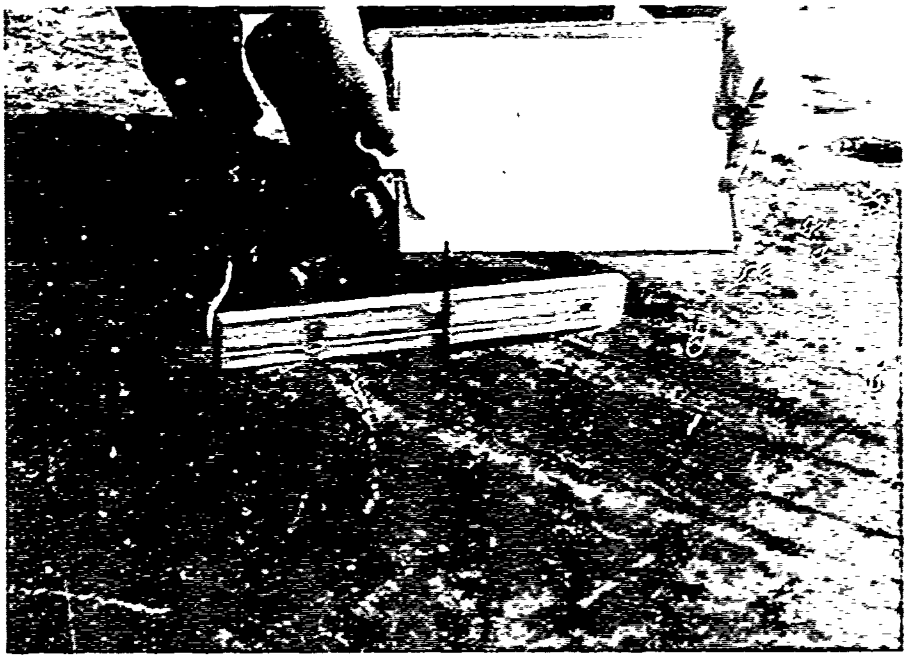

Figure 2. Typical pavement depressions caused by C-141

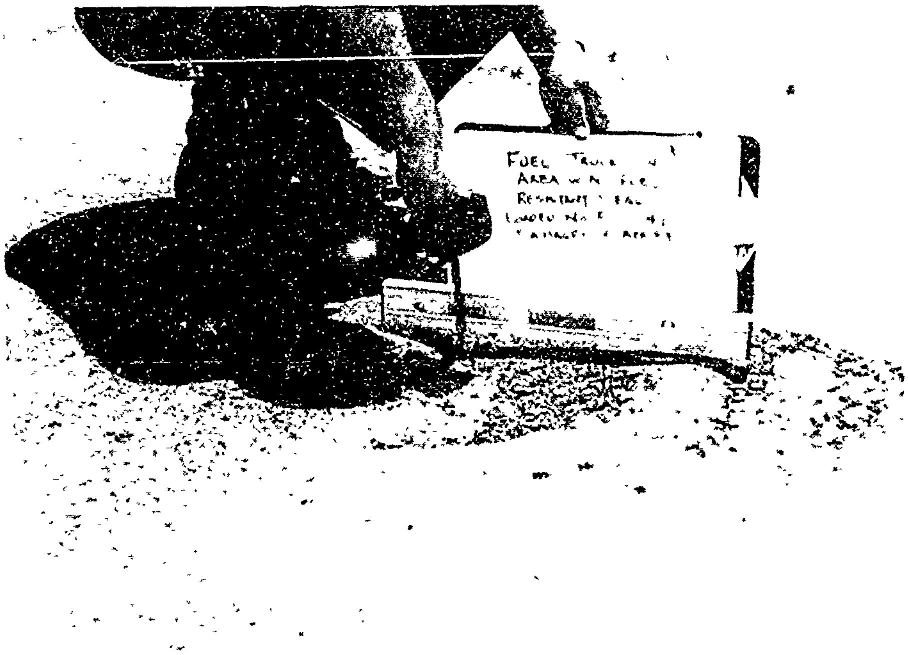

Figure 3. Pavement distress caused by fuel truck

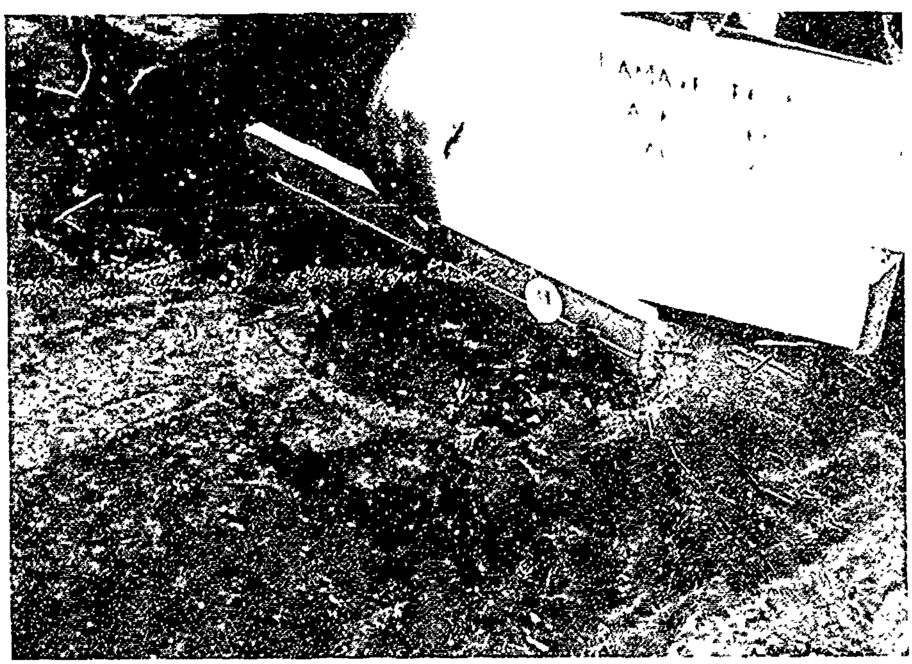

Figure 4. Pavement distress caused by loading jacks

PART II: LABORATORY ANALYSIS OF IN-PLACE PAVEMENT MATERIAL

Sample Description and Preparation

4. In June 1989, four slab samples of asphalt concrete from Cairo East Air Base were received at WES. These four samples were approximately 2 ft* by 2 ft in size and varied in thickness from 4.5 to 6.5 in. Each pavement sample consisted of a surface course layer, an intermediate course layer, and a single-bituminous surface treatment. Two pavement samples (S-3 and S-4) had a fuel-resistant sealer coating on the surface course layer. Figures 5 through 8 show the condition of the slabs at the time of arrival at WES.

5. Due to the unstable condition of the asphalt concrete pavement, it was decided that all pavement samples would be evaluated and that both surface course and intermediate course materials would be tested. Prior to any testing, the surface course and intermediate course layers were separated. All loose material that had been broken off the slab samples was discarded and not tested. The surface treatment that was attached to the bottom of the intermediate course and the fuel-resistant sealant that was on the top of the surface course were removed and discarded prior to the evaluation.

6. The first step in evaluating the in-place material was to determine the field density of the asphalt concrete layers. Due to the condition of the samples, cores could only be taken from one slab sample (S-4). For the other three samples, segments or chunks of the material were weighed in air and water to determine density values. Field density values for the surface course and intermediate course are given in Tables 1 and 2, respectively.

7. The next step in preparing the asphalt concrete material was to trim and remove all cut edges from the samples. This was accomplished by heating the cut edges and removing at least 3/4 in. of material with a hot spatula. This procedure is performed to ensure that the aggregate gradation is not affected by the sampling technique and that a true representative sample is evaluated. After this preparation was completed, the materials representing each of the eight samples were tested.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

Figure 5. Sample S-1, tire print from fifth C-141

Figure 6. Sample S-2, paint failure

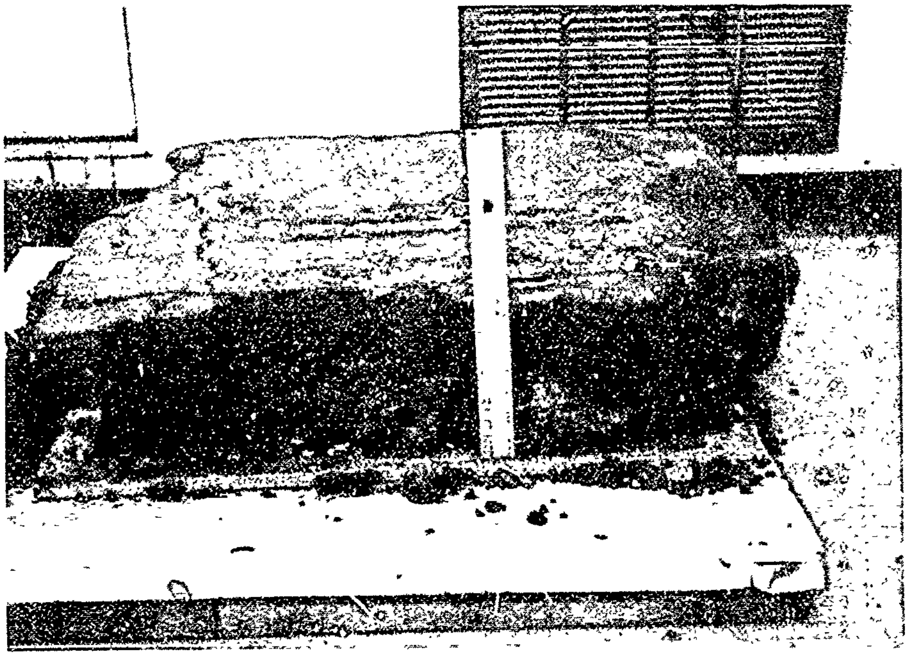

Figure 7. Sample S-3, tire print from second C-141

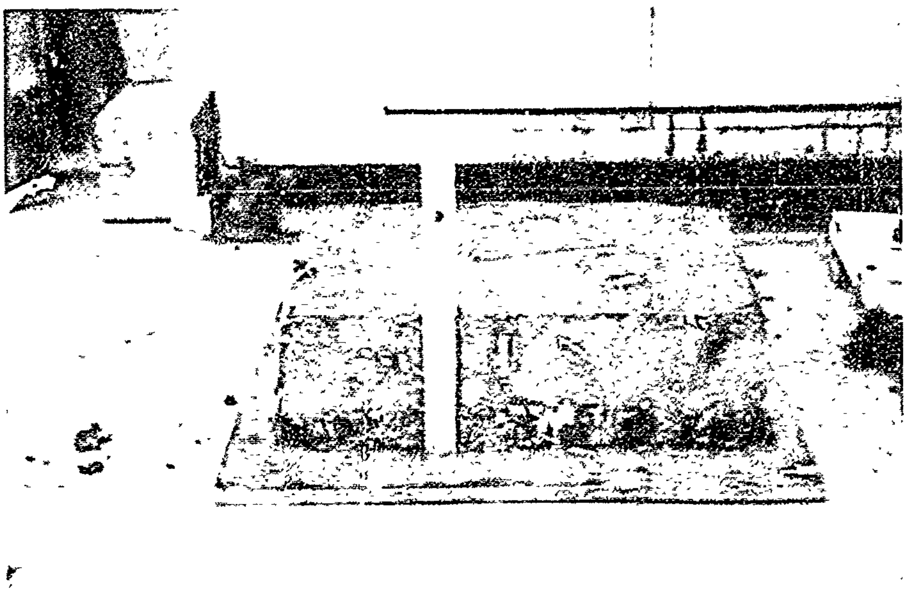

Figure 8. Sample S-4, no pavement distress

Table 1

Surface Course Field Density Analysis

Sample	No.	Thickness (in)	Specific Gravity	Density (pcf)
S-1	1	2 1/4	2.237	139.6
	2	2 1/4	2.275	141.9
	3	2 1/4	2.274	141.9
	AVG	2 1/4	2.261	141.1
S-2	1	2 1/8	2.196	137.0
	2	2 1/4	2.154	134.4
	3	2 1/8	2.220	138.5
	AVG	2 1/8	2.190	136.6
S-3	1	2 1/2	2.289	142.8
	2	2 1/2	2.330	145.4
	3	2 1/2	2.308	144.0
	AVG	2 1/2	2.309	144.1
S-4	1	2 1/2	2.375	148.2
	2	2 1/2	2.359	147.2
	AVG	2 1/2	2.367	147.7

Table 2

Intermediate Course Field Density Analysis

Sample	No.	Thickness (in)	Specific Gravity	Density (pcf)
S-1	1	2 3/4	2.230	139.2
	2	2 3/4	2.224	138.8
	3	2 3/4	2.235	139.5
	AVG	2 3/4	2.230	139.2
S-2	1	2	2.201	137.3
	2	2	2.224	138.8
	3	2	2.231	139.2
	AVG	2	2.218	138.4
S-3	1	3	2.247	140.2
	2	3	2.261	141.1
	3	3	2.249	140.3
	AVG	3	2.252	140.5
S-4	1	2 1/2	2.299	143.4
	2	2 1/2	2.292	143.0
	AVG	2 1/2	2.295	143.2

Laboratory Tests

8. Of the eight samples evaluated, four represented surface course materials and four represented intermediate course materials. A complete evaluation of each sample included extractions, asphalt recoveries, and recompaction studies. Four asphalt extractions (ASTM D 2172), two aggregate gradations (ASTM C 136 and C 117) and one Abson recovery (ASTM D 1856) were conducted on each sample.

9. Extractions and recoveries were run on prepared material from each sample. Technical grade solvents and a two stage extraction procedure using a high-speed centrifuge were employed to optimize the results of this procedure. The aggregates obtained from this extraction procedure were used to run aggregate gradation, specific gravity, fractured face, and natural sand count tests. The results of these tests are summarized in Tables 3 and 4. The asphalt cements recovered from the Abson recovery procedure were used to run the penetration, viscosity, specific gravity, and ductility tests. The results of these tests are listed in Table 5. The aggregate gradations from the in-place material are compared to the specified gradation band and the job-mix-formula (JMF) supplied by the contractor in Figures 9 through 16.

10. The remaining asphalt concrete material for each sample was then used for a recompaction study. This material was reheated to approximately 250^{0} F and used to recompact seven Marshall specimens by applying 75 blows on each side with the hand hammer. Two additional samples were compacted using the Corps of Engineers gyratory testing machine (GTM) using 200 psi, 30 revolutions, and 1 deg gyration angle, which is equivalent to a 75 blow hand hammer compactive effort. This gyratory compaction was used to check for flushing of the specimen which indicates excess asphalt cement in the mix or an unstable mix. Of the seven recompacted Marshall specimens, four were used to run the standard Marshall mix test (MIL-620A, Method 100), and three were used to run the Retained Stability Marshall mix test (MIL-STD 620A, Method 104). The results of the recompaction study and Marshall mix tests are found in Tables 6 and 7.

Table 3

Surface Course Aggregate Analysis

Sieve Size	Specified Limits*	JMF	S-1	S-2	S-3	S-4
1 in.	--	--	[illegible]	100	100	100
3/4 in.	100	100	[illegible]	97.4	98.6	97.7
1/2 in.	82-96	95.3	[illegible].4	90.7	91.9	93.7
3/8 in.	75-89	77.7	[illegible].4	81.2	83.9	81.7
No. 4	59-73	58.1	[illegible]	56.1	61.6	58.1
No. 8	46-60	57.4	[illegible]4.1	49.0	48.7	44.4
No. 16	34-48	50.0	40.5	45.5	44.2	39.1
No. 30	24-38	39.0	33.1	35.1	36.0	31.6
No. 50	15-27	16.0	15.0	12.9	14.6	14.4
No. 100	8-18	8.0	6.8	4.3	6.2	6.7
No. 200	3-6	6.0	4.8	2.7	4.2	4.9
% Fractured faces (+No. 4)			90.8	93.1	97.0	95.9
(-No. 4)			100	99.6	99.8	98.8
Natural sand count (%)			35.4	40.9	38.5	34.4
Specific gravity (+ No. 4)			2.73	2.69	2.74	2.72
(- No. 4)			2.54	2.56	2.63	2.61

Note: Underlined data are outside specifications.
* Percent passing.

Table 4

Intermediate Course Aggregate Analysis

Sieve Size	Specified Limits*	JMF	S-1	S-2	S-3	S-4
1 in.	--	--	100	100	100	100
3/4 in.	100	100	96.6	93.2	96.8	96.7
1/2 in.	73-91	83.1	84.5	81.7	88.1	87.0
3/8 in.	63-81	63.4	76.1	70.4	78.2	77.6
No. 4	45-63	42.3	53.4	47.5	54.2	55.5
No. 8	32-50	41.9	43.4	38.9	43.0	44.1
No. 16	23-41	39.4	41.0	35.9	38.4	40.3
No. 30	15-33	29.6	33.4	29.8	29.8	33.0
No. 50	10-24	14.0	10.8	12.4	11.3	13.7
No. 100	7-17	8.6	3.7	6.0	3.6	6.1
No. 200	3-7	6.8	2.6	4.4	2.2	4.5
% Fractured faces (+No. 4)			83.1	86.8	92.4	94.1
(-No. 4)			98.3	99.6	100	100
Natural sand count (%)			37.2	30.7	34.2	35.5
Specific gravity (+ No. 4)			2.67	2.63	2.65	2.67
(- No. 4)			2.54	2.63	2.63	2.62

Note: Underlined data are outside specifications.
* Percent passing.

Table 5

Recovered Asphalt Cement Analysis

Test	S-1	S-2	S-3	S-4
	Surface Course			
Penetration (100 g, 5 sec, 77^0 F)	37	29	32	43
Viscosity (abs, 140^0 F, P)	7,439	16,495	6,287	4,059
Viscosity (kin, 275^0F, cSt)	690	989	649	538
Specific gravity	1.036	1.036	1.036	1.033
Ductility (5 cm/min, 77^0 F, cm)	54	--	68	--
	Intermediate Course			
Penetration (100 g, 5 sec, 77^0 F)	32	28	35	37
Viscosity (abs, 140^0 F, P)	15,036	30,417	5,731	8,634
Viscosity (kin, 275^0 F, cSt)	902	1,155	618	761
Specific gravity	1.033	1.030	1.036	1.036

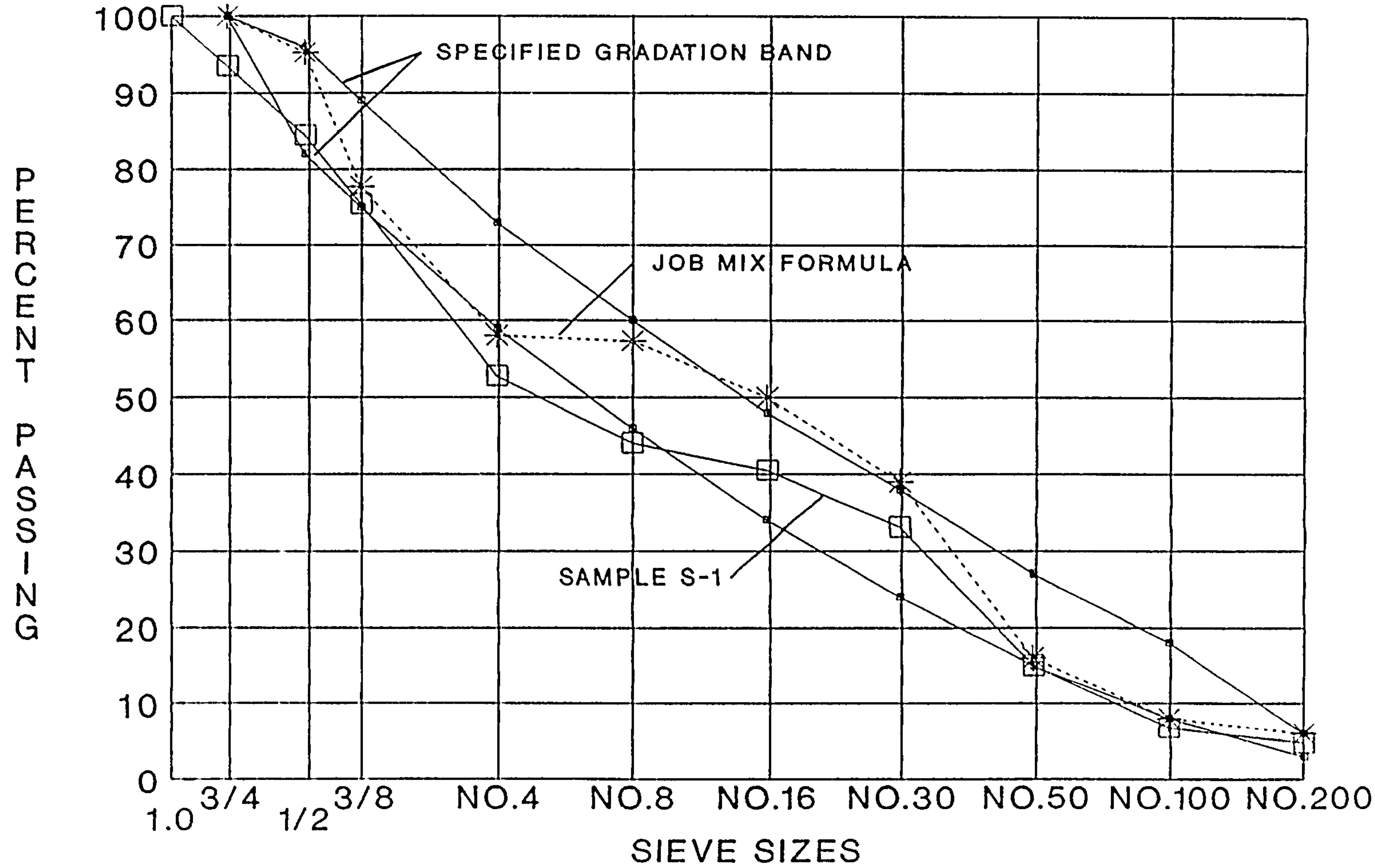

Figure 9. Surface course aggregate gradation, Sample S-1

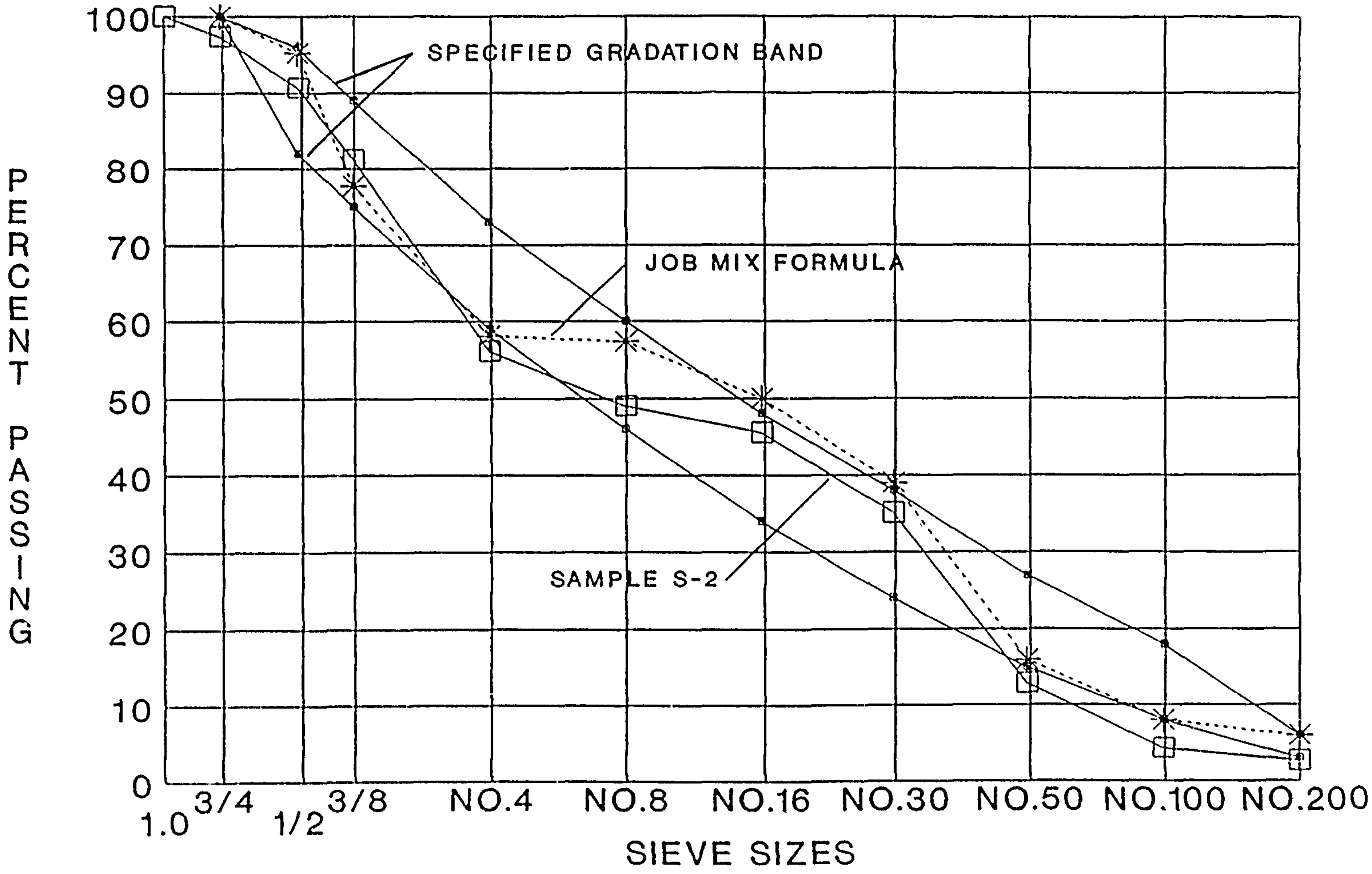

Figure 10. Surface course aggregate gradation, Sample S-2

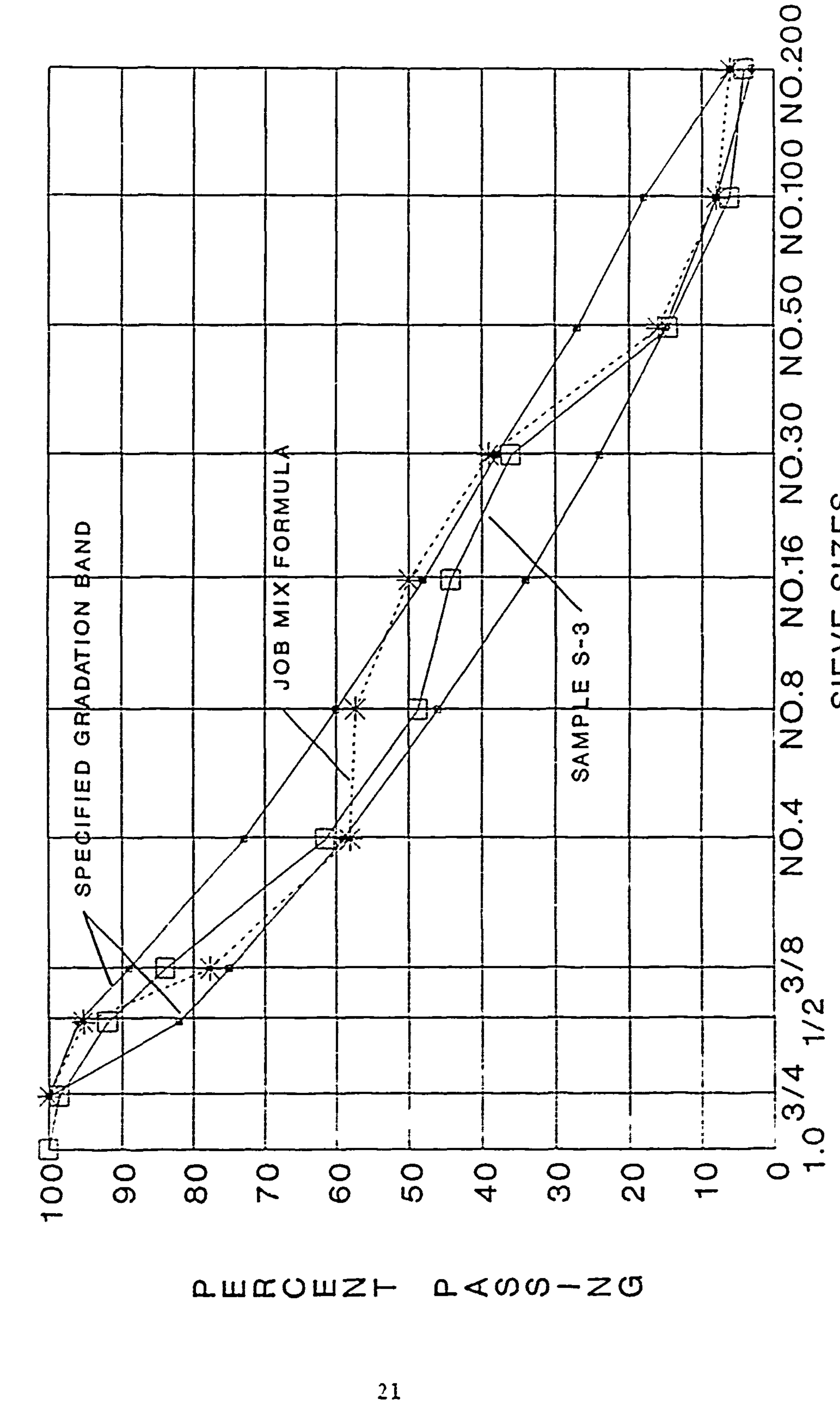

Figure 11. Surface course aggregate gradation, Sample S-3

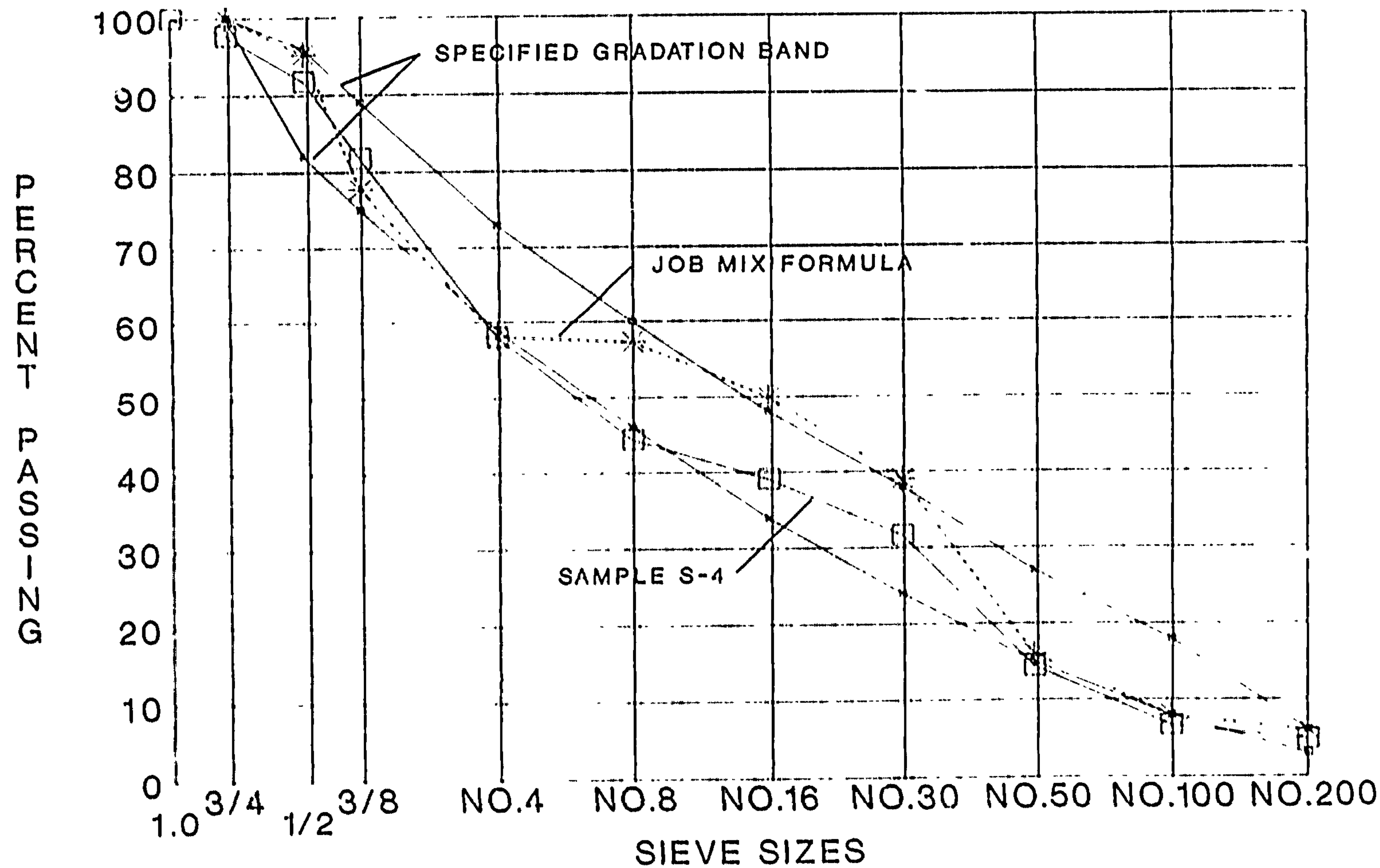

Figure 12. Surface course aggregate gradation, Sample S-4

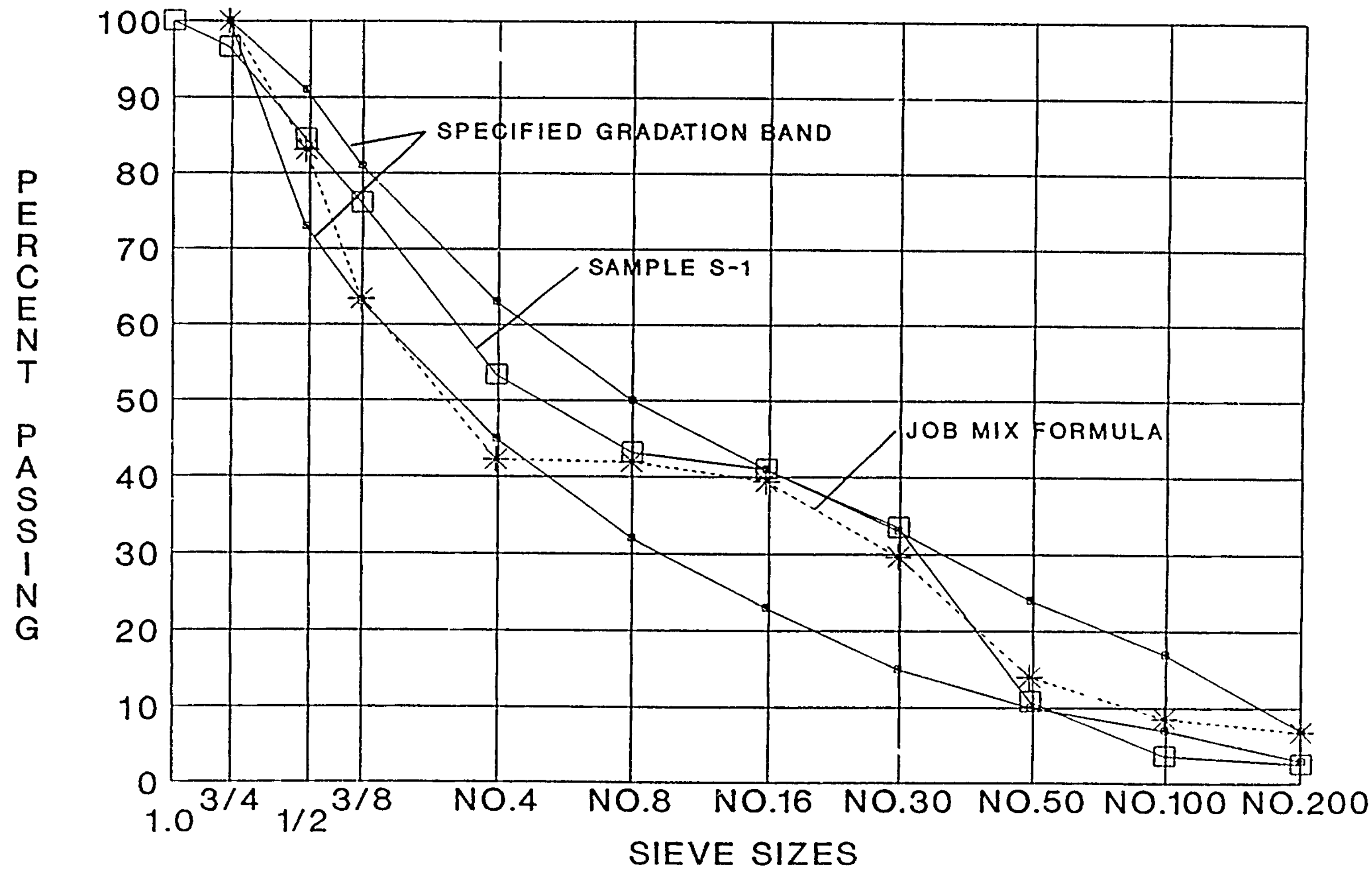

Figure 13 . Intermediate course aggregate gradation, Sample S-1

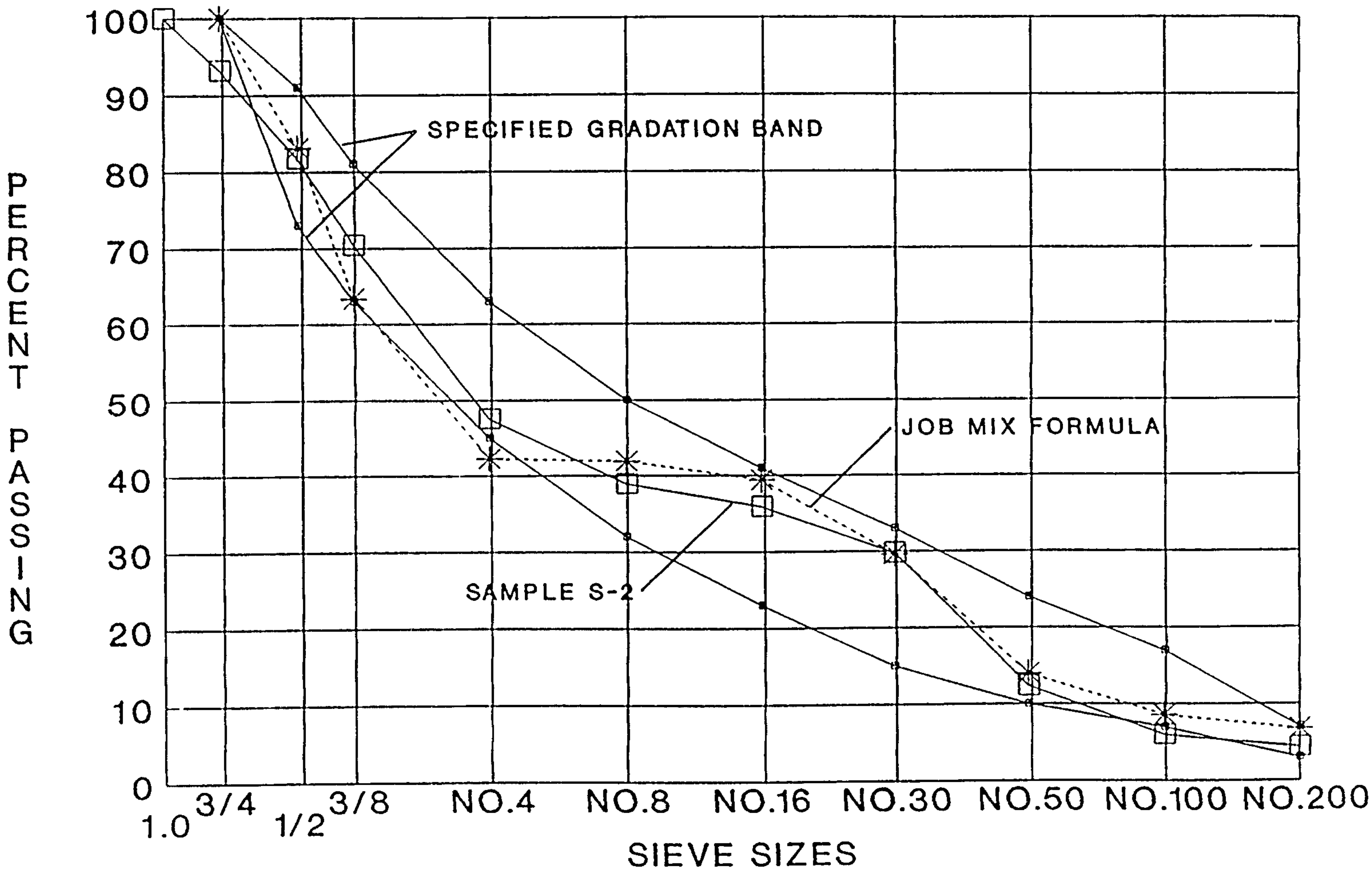

Figure 14. Intermediate course aggregate gradation, Sample S-2

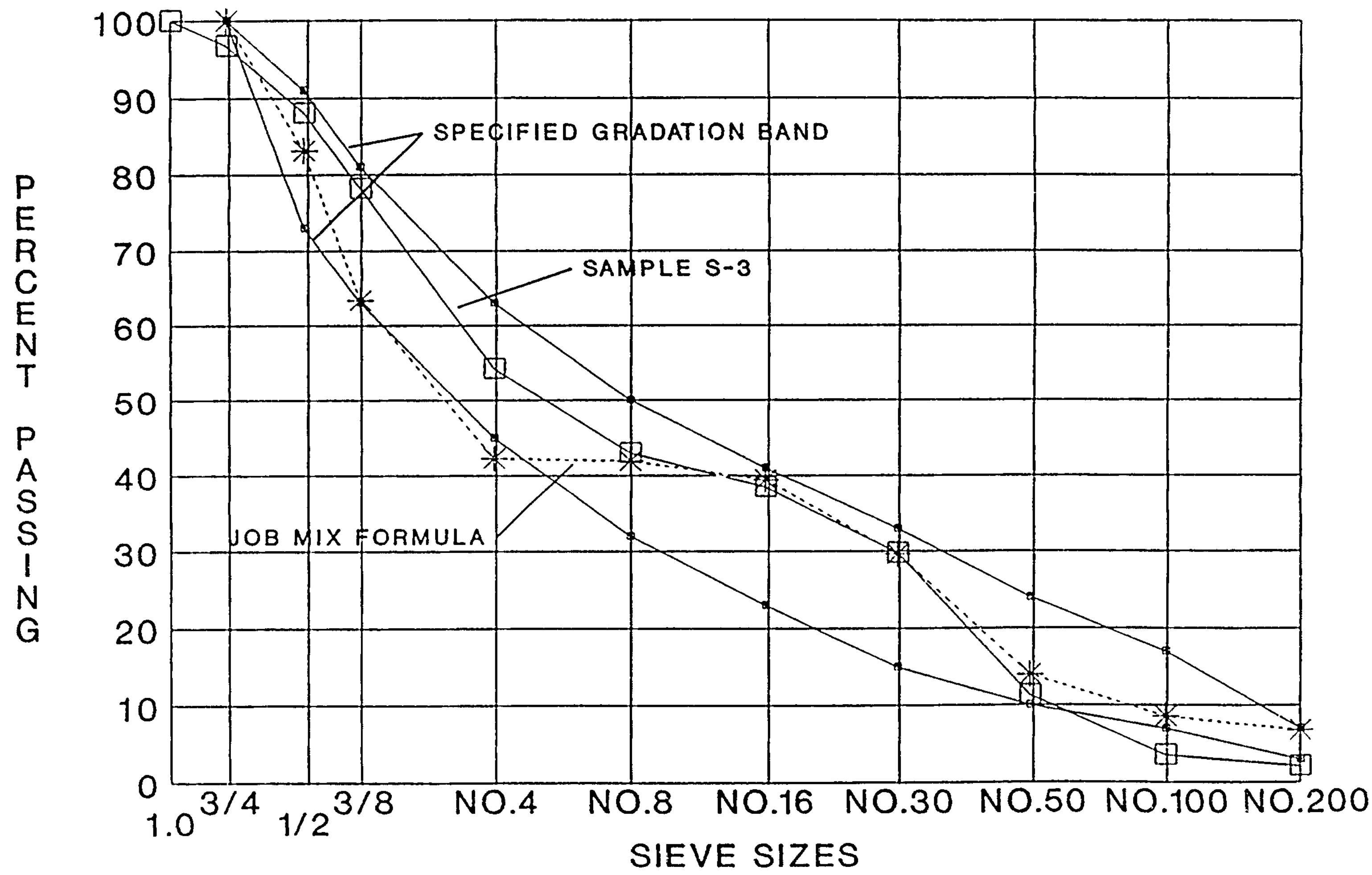

Figure 15. Intermediate course aggregate gradation, Sample S-3

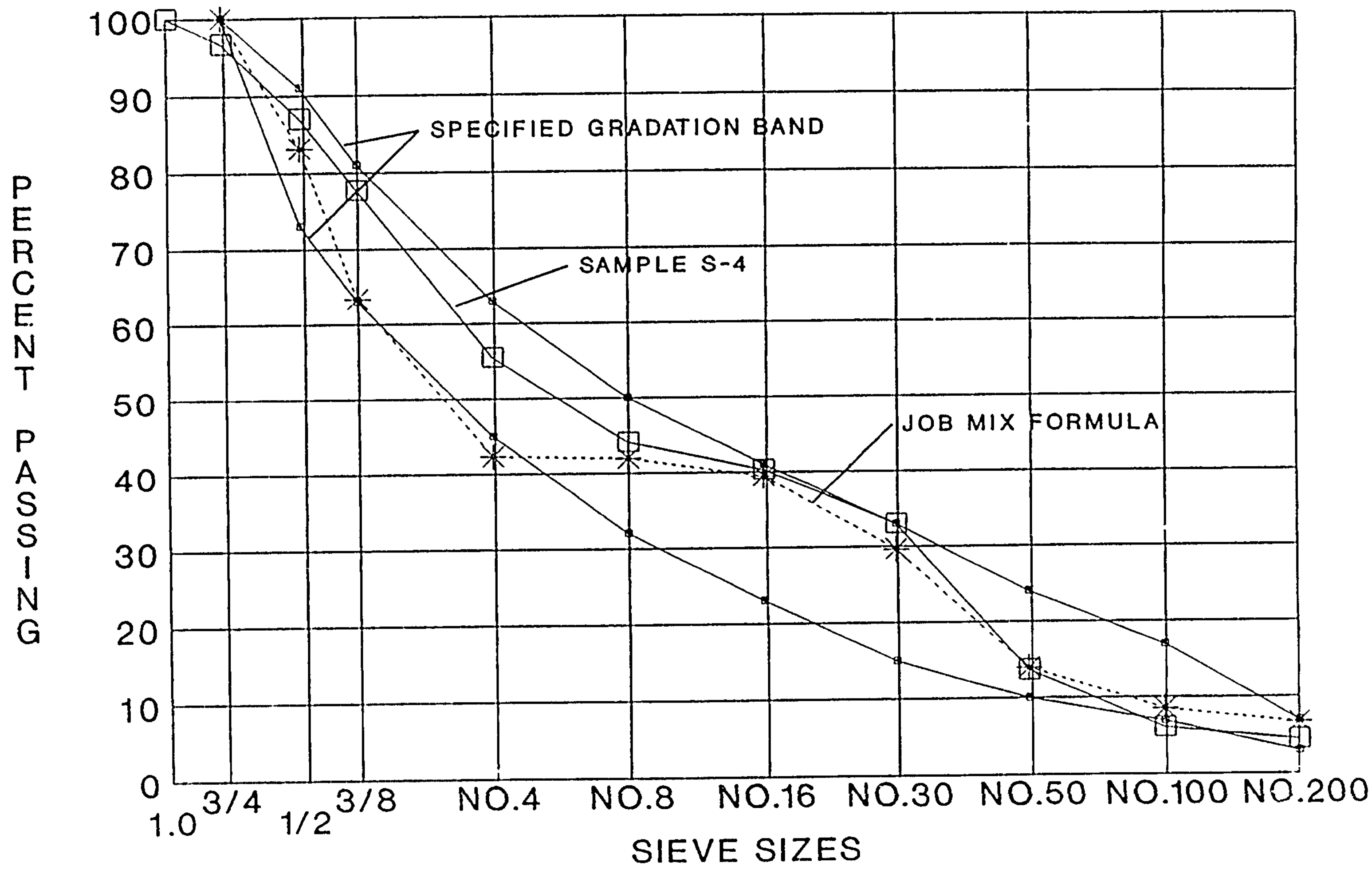

Figure 16. Intermediate course aggregate gradation, Sample S-4

Table 6

Surface Course Mixture Analysis

	Specs (JMF)	S-1	S-2	S-3	S-4
Asphalt content (%)	4.8	4.8	5.1	5.2	5.3
Stability (lb)	1,800 min	1,892	1,301	1,842	1,855
Flow (0.01 in.)	16 max	9	10	9	10
Voids total mix (%)	3 - 5	2.0	4.4	3.2	2.2
Voids filled (%)	70 - 80	84.7	72.2	78.9	84.8
Retained stability (%)	75 min	85.1	100	78.1	85.9
Gyratory flushing	--	Yes	Yes	Yes	Yes
Recompacted density (pcf)	--	149.7	144.8	149.1	149.5
Theoretical density (pcf)	--	152.6	151.4	154.1	152.9
Field density (pcf)	--	141.1	136.6	144.1	147.7
Percent compaction (%)	98 min	94.3	94.3	96.7	98.8

Note: Underlined data are outside specifications.

Table 7

Intermediate Course Mixture Analysis

	Specs (JMF)	S-1	S-2	S-3	S-4
Asphalt content (%)	4.75	5.0	4.2	4.8	4.7
Stability (lb)	1,800 min	1,373	2,186	1,334	1,909
Flow (0.01 in.)	16 max	9	9	9	9
Voids total mix (%)	5 - 7	4.7	5.8	5.4	5.9
Voids filled (%)	50 - 70	70.3	62.1	66.7	64.2
Retained stability (%)	75 min	81.4	97.5	81.2	77.6
Gyratory flushing	--	Yes	Yes	Yes	Yes
Recompacted density (pcf)	--	143.7	145.2	145.0	144.6
Theoretical density (pcf)	--	150.8	154.1	153.3	153.7
Field density (pcf)	--	139.2	138.4	140.5	143.2
Percent compaction (%)	98 min	96.9	95.3	96.9	99.0

Note: Underlined data are outside specifications.

PART III: DISCUSSION OF LABORATORY RESULTS

Field Density

11. The field density results listed in Tables 1, 2, 6, and 7 show inconsistent results between cored samples and chunk samples. The percent compaction values were determined using the field density and recompacted density values. The average field compaction for cored samples (S-4) for both the surface course and intermediate course material is above the specified 98 percent minimum compaction requirement. The average field compaction for the chunk samples (S-1, S-2, S-3) is below the minimum compaction requirement. The compaction values for the chunk samples ranged from 94.3 to 96.9 percent Due to the fact that field core specimens were not available for all samples, a true indication of the in-place density could not be determined.

Aggregate Analysis

12. The sieve analysis results listed in Tables 3 and 4 and shown in Figures 9 through 16 indicate that all samples have aggregate gradations that do not meet specifications. The primary problem with the aggregate gradation for both the surface course and intermediate course mixtures is that the gradations are gap graded instead of well or dense graded. Normal gradations for high tire pressure pavements are dense graded and do not vary from the upper to lower limits of the specified gradation limits Asphalt concrete mixtures that have gap-graded gradations generally tend to be less stable than dense graded materials.

13. The sieve analyses for the surface course material indicate that coarser than specified material (plus 3/4 in.) is in the asphalt concrete mixture and that there is a shortage of material passing the No. 4, No. 8, No. 50, and No. 100 sieves. The sieve analyses for the intermediate course also indicate coarser material has been added to the mixture and that there is a shortage of No. 100 material. The shortage of the finer-sized material will decrease the stability of the asphalt concrete. As a whole, the aggregate gradations are not acceptable for heavy duty airfield pavements.

14. The natural sand content was determined by visually observing the aggregate particles smaller than the No. 4 sieve under a microscope. The percentage of natural sand is calculated by determining the number of sand particles versus crushed aggregate particles.

15. The amount of natural sand in the aggregate gradation is extremely high. The natural sand count for the surface course material ranges from 34.4 to 40.9 percent, and the intermediate course gradation has sand counts between 30.7 and 37.2 percent. The maximum amount of natural sand allowed by the contract specifications is 15 percent. Too much natural sand is a primary cause of unstable or tender asphalt concrete mixes.

Asphalt Cement Analysis

16. The test results for the recovered asphalt cement are shown in Table 5. The results indicate that this material has typical values for a 60 to 70 pen asphalt cement that has been recovered from an asphalt concrete mixture. The recovered penetration of the asphalt cement varied between 29 and 43 for the surface course and 28 to 37 for the intermediate course. The typical initial percent loss for penetration values in an asphalt concrete mixture is 40 to 50 percent. These penetration values are in or near that range. The ductility test was also conducted on recovered asphalt cement from two surface course samples; the results were 54 to 68 cm. Both of these values exceed the minimum ductility requirement for an aged asphalt cement as stated in ASTM D 946.

Asphalt Concrete Mixture Analysis

17. Tables 6 and 7 display the laboratory test results for the recompacted asphalt concrete mixtures. The results indicate that the asphalt concrete mixtures are inconsistent and do not meet specifications in many instances. The aggregate blends of all samples have a water absorption below 2.5 percent and are, therefore, considered nonabsorptive. Each surface course sample has at least one asphalt concrete mixture property requirement that is not met. As mentioned previously, all aggregate gradations are out of specification. Samples S-1 and S-4 have very low voids total mix of 2.0 and

specification. Samples S-1 and S-4 have very low voids total mix of 2.0 and 2.2 percent, respectively, and high voids filled with asphalt of 84.7 and 84.8 percent, respectively. The asphalt content values are generally higher than the JMF recommended value, especially Samples S-3 and S-4. The stability value for Sample S-2 is extremely low and unacceptable. The reported stability values for Samples S-1, S-3, and S-4 are above the minimum 1,800 lb, but these values are misleading. Recompaction stability values are usually higher than the stability of the mixture when it was placed because the asphalt material has been reheated causing the asphalt cement to harden. The hardened asphalt material causes the stability values to be high. Based on these data, the surface course material would not meet the requirements of the specifications and was not suitable for an airfield pavement.

18. The Marshall properties of the intermediate course are acceptable except for the stability values. Samples S-1 and S-3 have very low stability values of 1,373 and 1,333 lb, respectively. Samples S-2 and S-4 are above the 1,800 lb minimum requirement, but because these samples have been heated and reheated, the stability values are considered to be higher than the actual stability value when it was produced. Based on these data, the intermediate course material would not meet the requirements of the specifications.

PART IV: INSPECTION OF CONSTRUCTION SITE

19. In February 1990, MEAPO requested technical assistance during the repair and continued construction of the airfield pavement. The purpose of this visit was to monitor the production and construction of an additional portion of the airfield pavement. MEAPC requested that a complete inspection be conducted on the quarry, asphalt plant, and testing laboratory.

20. The aggregate quarry site was visited to observe the crushing operation. The material being crushed was similar to a pit-run gravel that was excavated from the existing terrain by a front-end loader. The size of the unprocessed material ranged from small boulders to fine aggregates. Approximately 50 percent of the material being processed was estimated to be minus No. 4 material, natural sand. A typical load of material that was processed and crushed is shown in Figure 17. Located at the beginning of the crushing operation was a grizzly, a device designed to discard all material smaller than 3 in. The grizzly was not functioning properly because it was partially blocked (Figure 18), and the feed rate was too high for this short 6-ft grizzly. Both of these problems allowed uncrushed minus 3-in. material to pass through the crushing operation without being fractured. All stockpiles contained uncrushed particles. A typical example of uncrushed particles in the aggregate stockpiles is shown in Figure 19. It was estimated that between 20 and 40 percent of the material being processed was smaller than the No. 4 sieve and was not crushed. It was suggested that the minus No. 4 material be removed from the aggregate prior to crushing to ensure that natural sand and uncrushed materials were not contaminating the crushed stockpile. This could be accomplished by screening the material prior to placing it in the jaw crusher or ensuring that the grizzly functioned properly.

21. The asphalt plant was visited to observe plant operations. The asphalt plant was a Barber Green batch plant that was approximately 2 years old and had a capacity of 4 tons per batch. The aggregate stockpiles at the asphalt plant were contaminated with fine material (Figure 20). The handling of these materials was inconsistent with good stockpile management methods. The loader operator was picking up natural fine material off the underlying ground surface and mixing this material with the aggregate stockpiles. The

cold feed bins were also being overfilled by the loader operator which resulted in material spilling over into the adjacent bins. The asphalt concrete material was produced at an extremely high mixing temperature of 350^0 F.

22. The testing laboratory was also inspected. The field laboratory was located adjacent to the parking apron. The laboratory was set up to run gradations, asphalt contents, and Marshall tests. The Marshall stability and flow tests were observed along with the compaction of several samples. The laboratory compaction of the asphalt concrete material was normally conducted with a mechanical hammer that had not been calibrated to correlate with a hand hammer. Marshall specimens were compacted according to MIL-STD 620 with hand hammer during this visit. The main problem observed with asphalt concrete testing was placing the uncompacted asphalt concrete mixture in the oven and reheating the material for several hours before laboratory compaction.

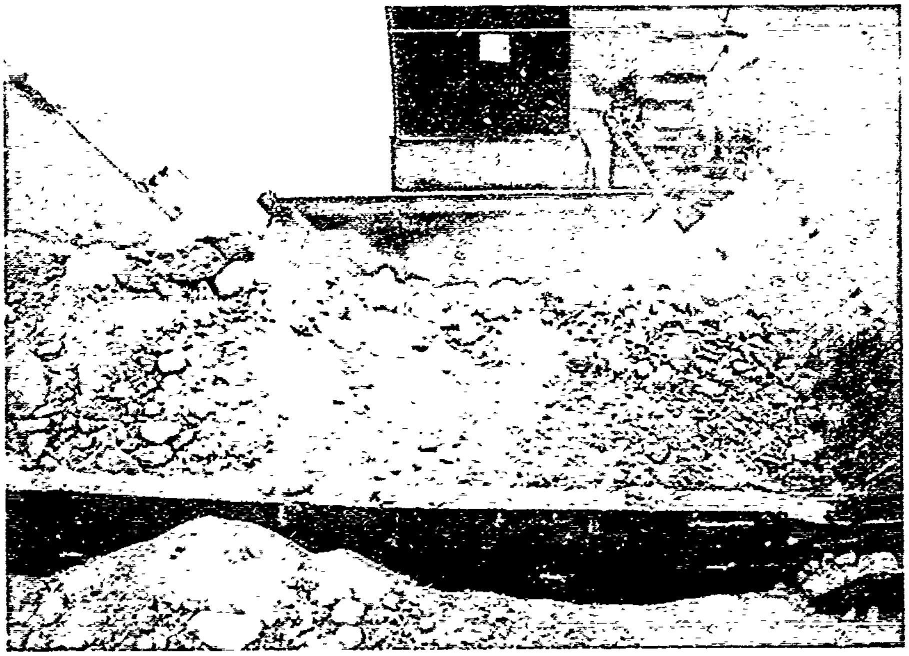

Figure 17. Typical example of unprocessed material

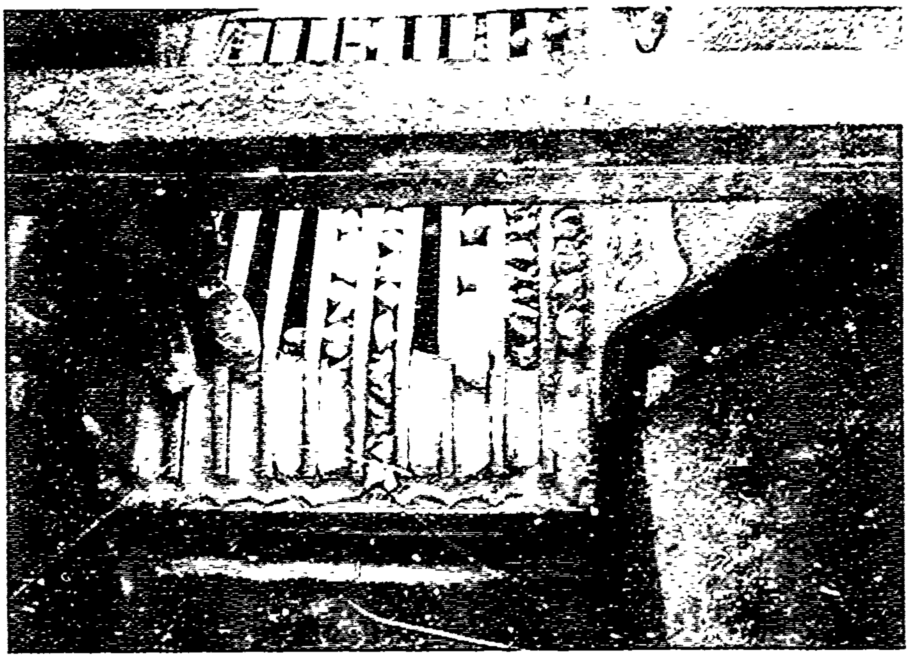

Figure 18. Partially blocked grizzıy

Figure 19. Example of uncrushed particles in aggregate stockpiles

Figure 20. Contaminated aggregate stockpile

PART V: LABORATORY ANALYSIS ON EFFECT OF HEATING ASPHALT CONCRETE SPECIMENS

23. During this entire project, laboratory data from the field laboratory indicated the stability of the asphalt concrete mixtures was acceptable, and the stability values determined at WES were always lower than the field laboratory results. After observing no major errors in the field laboratory operations, it was determined that the differences in stability values were caused by the difference in heating and mixing of the asphalt concrete material. Standard laboratory mixing and compaction temperatures used at WES were lower than the temperatures used to produce the asphalt concrete material at the asphalt plant.

24. The sensitivity of the original asphalt cement had been questioned since the laboratory tests indicated that 60-70 pen asphalt did not meet the requirements of ASTM D 946. The test results for this asphalt cement are listed in Table 8. The asphalt cement testing indicated that this material had the potential to lose lighter fractions. This asphalt cement had a large weight loss and a large decrease in penetration after the thin film oven test. This indicated that the material had a tendency to harden significantly when subjected to heat.

25. A laboratory study was conducted to determine the effect of excessive heating by leaving the asphalt concrete material in the oven for an extended time before compaction. Several asphalt mixtures consisting of labstock limestone aggregate and the original 60-70 pen asphalt cement from Egypt were mixed at 250 and 350° F and stored in an oven at each temperature prior to compaction. The "cure time" in the oven prior to compaction varied from 0 min to 24 hr. The results of this study are listed in Table 9 and are shown in Figures 21 and 22. The stability values increased tremendously with extended time in the oven, especially at the higher temperature. The increase in stability at 250° F was 35.3 percent at 4 hr and 92.9 percent at 24 hr. The increase in stability values at 350° F was 288.4 percent at 4 hr. This increase in stability indicated the asphalt cement was very sensitive to heat and age hardening.

Table 8

The 60-70 Pen Asphalt Cement Properties (ASTM D 946)

Test	Requirements	Sample 1	Sample 2
Penetration, 77^0 F, 100 g, 5 sec, 0.1 mm	60-70	70	67
Flash point-cleveland open cup; F	450 min	520	530
Ductility, 77^0 F, 5 cm/min, cm	100 min	<u>66</u>	<u>64</u>
Solubility in trichloroethylene, %	99.0 min	99.9	99.9
Test on residue from TFOT			
Weight loss, %	--	0.44	0.55
Penetration, 77^0 F, 100 g, 5 sec, 0.1 mm	--	36	36
Retained penetration, %	52 min	<u>51</u>	55
Ductility, 77^0 F, 5 cm/min, cm	50 min	<u>18</u>	<u>18</u>

Note: Underlined data are outside specification.

Table 9

Effect of Heating Asphalt Concrete Specimens

Time (min)	Stability 250° F * (lb)	Percent Increase (%)	Stability 350° F * (lb)	Percent Increase (%)
0	2,184	--	2,107	--
30	2,181	--	--	--
60 (1 hr)	2,143	--	3,069	45.6
120 (2 hr)	2,658	21.7	4,633	219.9
240 (4 hr)	2,954	35.3	6,076	288.4
1,440 (24 hr)	4,213	92.9	--	--

* Asphalt concrete specimens were mixed and cured in oven prior to compaction at 250 and 350° F. A 75-blow hand hammer was used to compact all specimens.

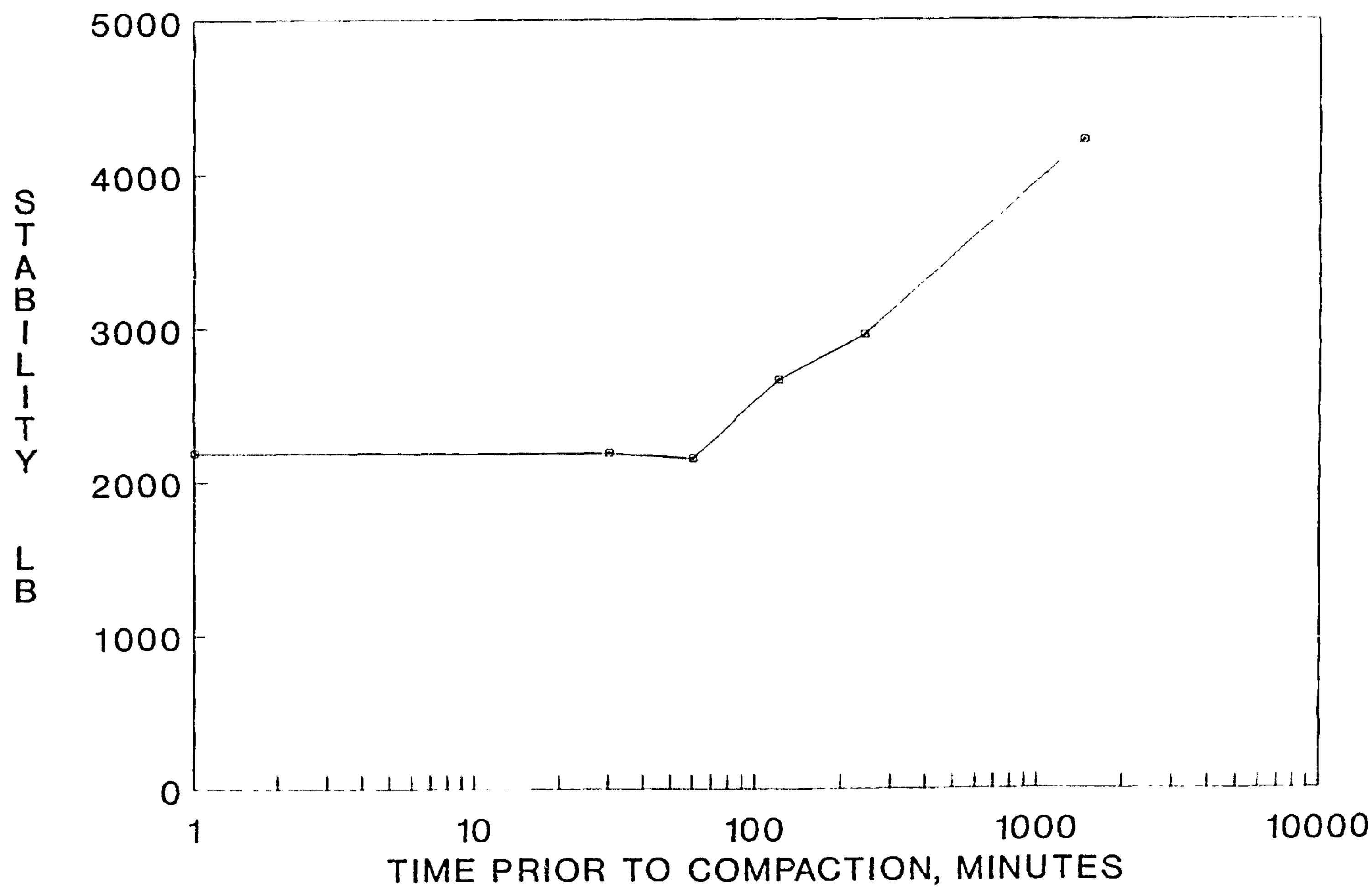

Figure 21. Cure time versus Marshall stability, 250° F compaction temperature

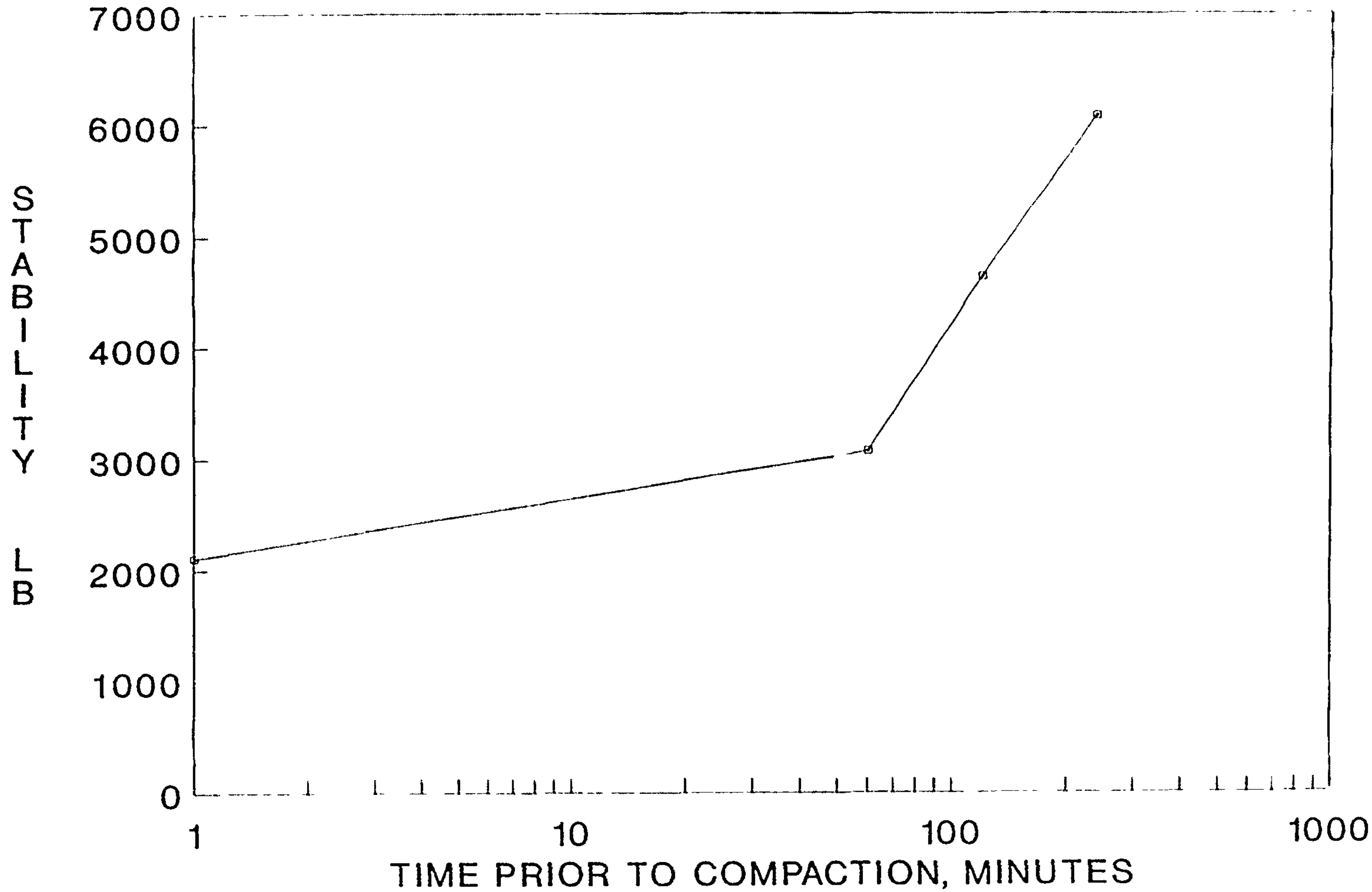

Figure 22. Cure time versus Marshall stability, 350° F compaction temperature

PART VI: SUMMARY

26. The performance of the asphalt concrete has been unacceptable due to depressions and deformation caused by normal aircraft traffic on the parking apron. Based on the test results, an evaluation of the mix designs, and an inspection of the construction site, the poor performance of the asphalt concrete was due to an improperly designed and produced asphalt concrete mixture. Several factors that contributed to this improper mixture are listed below:

a. Aggregate gradation. The aggregate gradations were consistently out of specification and were gap graded. Gap-graded aggregate gradations are not used for heavy duty airfield pavements because these materials are less stable and have the potential to rut and deform.

b. Natural sand. The amount of natural sand in both the surface course and intermediate course materials was extremely high. Tender mixes often result from the use of an excessive amount of natural sand. This excessive amount of rounded sand particles acts like ball bearings causing the mixture to be unstable. The excess natural sand is a major contributor to the instability of these mixtures.

c. Mix designs. The JMF for both the surface course and intermediate course mixtures did not meet specifications. The aggregate gradations for both mixtures did not meet the specified limits of the contract. The amount of natural sand used in the JMF for the surface course material was 52.5 percent. Thirty-five percent natural sand was used in the JMF for the intermediate course. Both of these values exceed the limit specified in the contract specifications. The mix designs produced for this project are not acceptable for a heavy duty asphalt concrete pavement.

d. Asphalt cement. The original asphalt cement tested and evaluated from these samples indicates that this material was sensitive but was not the cause of the pavement deformation. However, the 60-70 pen asphalt cement was very sensitive to heat and was affected significantly when exposed to high temperatures for an extended amount of time. The hardening of this asphalt cement increased the stability values tremendously and produced misleading field laboratory results.

e. Site visit. The aggregate quarry and asphalt plant were operating in an insufficient manner to produce high-quality materials for an airfield pavement. The quarry was not functioning properly and was allowing a large percentage of the uncrushed material to pass through the crushing operation, thus contaminating the crushed stockpiles. The handling procedures at the asphalt plant further

PART VII: RECOMMENDATIONS

27. Based on the inspection of the construction site and the laboratory analysis of the in-place asphalt concrete at Cairo East Air Base, the following recommendations are given:

a. The in-place asphalt concrete material including the intermediate and surface course layers are unacceptable for airfield pavements and should be removed. The entire asphalt concrete overlay should be removed either by cold milling or by ripping the material out with heavy construction equipment.

b. The taxiway and aircraft parking apron should be reconstructed with asphalt concrete produced and placed according to the specification. An asphalt concrete pavement will be an adequate surface for the airfield if proper materials and construction practices are used in the rehabilitation. Aircraft parking aprons have been constructed of asphalt concrete throughout the world in both hot and cold climates and have had satisfactory performance.

c. Asphalt concrete pavements should not be constructed if substandard materials and mix designs are to be used.

d. The operations at the aggregate quarry and asphalt plant should be modified to meet standard construction practices.